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# BLOSSOM-END ROT OF TOMATOES

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# BLOSSOM-END ROT OF TOMATOES[1]

CHARLES BROOKS

WITH PLATES XXIV, XXV AND XXVI, AND FIVE FIGURES IN THE TEXT

Blossom-end rot or point rot of tomatoes is of general occurrence in the United States and has been reported from Canada, Cuba, Australia, New Zealand and from various parts of Europe.

Galloway (1888) appears to have been the first to describe the disease. He spoke of it as a blackish spot that appeared near the style when the fruit was one-half or two-thirds grown, rapidly increasing in size and finally spreading deep into the tissue of the fruit; the affected tissue becoming black, hard, and leathery and the tomato much flattened.

Later writers have given similar descriptions, indicating that the different observers have been considering diseases that were at least alike in general appearance. Stewart (1896) called attention to a slight watery discoloration which preceded the blackening of the fruit and which he regarded as the first symptom of the disease.

A great many different agencies have been given as the cause of the disease. Galloway (1888) found that *Macrosporium tomato* Cooke produced the rot rapidly when it had gained entrance to either green or ripe fruit, but that it was unable to penetrate the sound cuticle. Rolfs (1893) attributed the disease to *Macrosporium solani;* Prillieux and Delacroix (1894) to bacteria; Earle (1900) to bacteria; Oven (1905) to *Fusarium erubescens* Appel and V. Oven; Quinn (1905) to *Macrosporium tomato;* Miss E. H. Smith (1907) to a species of Fusarium and to a species of Bacillus; Smith (1907) and others to bacteria. Stevens and Hall (1910) reported the disease as an infective one. Selby (1897), Orton (1907), Price (1910), Fulton (1911) and others have held that the disease is not due to either fungi or bacteria.

Howell (1890), Rolfs (1893), and Ferris (1907) have reported the control of the disease by spraying. Quaintance (1900), Orton (1907), Jarvis

[1] The writer is indebted to the Bur. Plant Ind. U. S. Dept. Agr. for the opportunity of growing one of the several crops of tomatoes mentioned in this publication.

(1909), and Barre (1910) obtained negative results from spraying, and most writers on the subject have considered spraying of little value in controlling the disease.

The majority of the more recent workers have held the disease to be of a physiological nature, and some of those who have attributed it to the presence of foreign organisms have called attention to physiological conditions as modifying factors. Quinn (1905) thought that heavy applications of nitrogenous manure increased the disease. Quinn (1905) and also Price (1910) reported that the disease was decreased by staking or by other means of keeping the tomatoes from the ground. Orton (1907) and Ruggles and Stakman (1911) reported the disease more serious on light soils. Quinn (1905) held that excessive watering favored the disease. Selby (1897), Orton (1907), Jarvis (1909), Ruggles and Stakman (1911), and Reed (1911) have all reported dryness as favoring the disease. Most of the last named writers considered lack of water the chief cause of the trouble.

During the progress of the work reported in this paper, several publications have appeared on the subject. Stone (1911) reported the results of extended experience with greenhouse tomatoes. He found that the entrance of bacterial organisms through cracks near the blossom of the fruit was largely responsible for the trouble and that strong sunlight, rapid transpiration, heavy applications of fertilizer, and especially dryness increased the disease by favoring the development of these cracks in the fruit.

Stuckey and Temple (1911) found the disease to be non-infectious. They made extensive field studies, using twelve one-eighth acre plats for the work. They concluded that there was nothing in the use of nitrate of soda or stable manure to increase the tendency to rot; that staking increased it and that the disease could be controlled if not entirely prevented by keeping an abundant supply of water in the soil. They found that there was a great difference in the susceptibility of different varieties.

Güssow (1912) considered drouth the probable cause of the first stages of the disease.

Bailey (1913) reported the disease more serious in dry weather and on light soils. He found that there was evidence indicating that it is an infective disease, the cause of which is distributed by insects.

Groenewege (1913) found the disease to be due to *Phytobacter lycopersicum* n. sp. He considered the organism a wound parasite. Infection experiments in a house kept at 28°–30°C. gave negative results; so also did his inoculations on green tomatoes in a cool house. Inoculations in the latter house on fruit that was just beginning to turn yellow gave positive results. He considered the contrast in the results to be due to the greater acidity of the green fruit and called attention to a predisposition to the

disease as a matter of importance. He found that continuous planting of tomatoes on the same soil favored the disease and that the renewal of the soil to a depth of 10 or 12 inches very greatly reduced the amount of the trouble in forcing houses. He observed that the lower tomatoes became infected first and considered the soil as the source of infection. He gave a full discussion of the cultural characteristics of the organism concerned and of the enzymes it produced.

Wicks (1913) reported the disease worse on light soil and in dry weather.

Rogers (1913) considered lack of moisture the responsible agency in the development of the disease.

## GENERAL CHARACTERISTICS OF THE DISEASE

The observations of the writer on the appearance of the blossom-end rot agree in general with the description already given. A watersoaked appearance on the blossom portion of the fruit is usually the first evidence of the trouble (see plate XXIV). The affected tissue may at first be a spot at the base of the style, or one half a centimeter or more away from it, or, as is more commonly the case, the whole blossom surface of the fruit may become affected at the same time. The trouble at this stage has an appearance somewhat similar to a bruise. In a few days this dark green, watersoaked area becomes black (see plate XXIV, figs. 6 and 10). Later the whole blossom half of the fruit may be involved. The affected tissue collapses and becomes firm and leathery. This collapsing of the diseased tissue, together with the continued development of other parts of the fruit may produce a definite depression on the blossom half of the fruit (see plate XXIV, figs. 6 and 7), but more often it results in only a flattening of the tomato (see plate XXIV, fig. 9).

The first effects of the disease are not always superficial. Fruit that appears entirely normal from an external view often has the tissue of several or sometimes all of its placentae collapsed and blackened in the parts nearest the blossom (see plate XXIV, figs. 2 and 11). In some cases this internal condition is accompanied by a very inconspicuous depression of the surface tissue above it or by a small watersoaked area on the surface (see plate XXIV, fig. 1).

## FUNGI, BACTERIA AND ENZYMES

A study was made of the foreign organisms associated with the rot. Affected tissue from early stages of the disease was introduced into various kinds of culture media with uniformly negative results. Fungi and bacteria were often obtained from cultures of later stages of the disease. The organisms occurring most frequently were a bacterium, apparently *Phyto-*

*bacter lycopersicum* Groenwege, and a species each of Penicillium, Macrosporium and Fusarium. The first two were the most common.

Inoculations were made into the blossom portion of tomatoes with each of the above organisms. Most of the inoculated tomatoes were about half grown, a stage at which the fruit seems particularly susceptible to the rot. Punctures made with a sterile needle caused no blackening of the tissue. The bacterium and the Penicillium blackened the tissue within a radius of about one millimeter around the puncture. Fruit inoculated with Fusarium or with Macrosporium developed a rot that bore a close resemblance to the late stages of that already described. These fungi, however, usually produced a growth externally, and the rots were more sunken and the tissue more collapsed and less firm than in the typical rot. They had a cheesy consistency instead of the usual leathery condition of the blossom-end rot.

The results showed that Penicillium and the bacterium were unable to produce blossom-end rot and that the troubles developed by Fusarium and Macrosporium were different from the disease in question. These latter organisms could also be excluded from the possible causal agencies on account of their very rare occurrence in the affected tissue.

It was thought possible that the disease might still be somewhat contagious and due to some substance of an enzymic nature. To test this point small pieces of diseased tissue were cut and carefully introduced into the blossom region of healthy fruit. Only negative results were obtained. This method necessarily led to considerable drying of the tissue and it was thought that extracts from the rot might be more effective. In obtaining these extracts the customary methods were followed, such as the addition of toluol, chloroform or alcohol, passing through a Berkefield filter or extraction under antiseptic conditions. The juice was injected into the tomato by means of a hypodermic syringe. Similar injections were made with extracts from normal green fruit, from normal ripe fruit, and from rot tissue. Negative results were obtained in all cases.

Similar tests were made in the laboratory by introducing diseased tissue and normal green tissue into the same tube of sterile water. The green tissue remained unchanged. Green tissue was also introduced into 15 per cent alcoholic solution of rot extract with negative results.

The results seemed to prove that the blossom-end rot is entirely noncontagious, and that a solution of the problem must be found along cultural and physiological lines.

## CULTURAL WORK[2]

The cultural work has extended over a period of five years and includes a study of more than eighteen crops of tomatoes. Plants were grown under various conditions in order to determine some of the factors influencing the disease. Careful records were kept of the effect of the different treatments upon the fruit and upon the plants as a whole. The plants grown outdoors were subjected to the various meteorological changes. Except where otherwise stated, the tests were made in the greenhouse. The temperature of the house was kept at 24° to 27°C. in the daytime and was allowed to drop about 5° at night. The air in the greenhouse was kept very humid but not so near the saturation point as is often found in tomato forcing houses. A complete record of temperature and humidity was not kept, but the plants compared were always under the same conditions of light, heat, moisture, and aeration. Various attempts were made to bring tomato plants to maturity in water cultures but without success. The plants reported upon were grown in candy pails. Drainage was secured by means of holes in the bottom of the pails. Except where otherwise stated the plants were watered from above in the usual manner. As mentioned later, some of the pails were set in pans and watered from below. The plants were pruned to a single stem and kept erect. They were transplanted from the seed bed to four-inch pots and from these to the candy pails. The soil used was a sandy clay loam with considerable finely divided turf and was renewed for each crop. When manure was added it was mixed with the soil used in the last transplanting. It was measured out separately for each pail, the amount being determined by volume or bulk. The chemical fertilizer applied was added to the top of the soil and worked into it. Little or no chemical fertilizer was used until the fruit was well set. It was then applied at fairly regular intervals and in the various quantities reported later. Except where otherwise stated, the fertilizer consisted of four parts (by weight) potassium chloride, two parts superphosphate, and one part sodium nitrate. The lots receiving a particular treatment consisted of from three to nine plants. The errors liable to result from using this comparatively small number of plants were obviated by careful control and by repetition of the tests with different varieties and in different lots. All plants showing signs of weakness or abnormality were discarded at the time of beginning the various treatments. The plants of a particular lot were scattered through the house in order to prevent the results from being affected by any peculiarities in light or air currents.

[2] The writer is indebted to R. B. Piper for the growth and care of most of the tomatoes used in these experiments.

### COMPARATIVE SUSCEPTIBILITY OF VARIETIES

Several varieties of tomatoes were tested under like conditions to determine their relative susceptibility to the disease. The plants were grown in candy pails in the open. They were heavily watered and each plant received 156 grams of commercial fertilizer during the season. The results are shown in the following table.

| *Variety* | *Per cent of rot* |
|---|---|
| Bonny Best | 0.0 |
| Stone | 15.6 |
| Golden Queen | 16.6 |
| Earliana | 28.1 |
| Ponderosa | 35.3 |
| Comet | 36.0 |
| Lorillard | 39.6 |
| Rocheford | 47.9 |
| Matchless | 50.0 |

The results are in close agreement with those reported in Stuckey and Temple's (1911) recent publication and indicate that considerable of the difficulty in regard to the disease can be avoided by proper selection of varieties. Many of the susceptible varieties, however, are too popular with growers to be readily discarded and the general prevalence of the disease and its probable similarity to troubles on other plants made a further understanding of its nature a matter of importance.

### FORCING

One of the most conspicuous things in the results from cultural experiments has been the effects of forcing. In general the most vigorous plants have been the most susceptible to the disease. Several of the experiments made in the beginning of the work gave no results of interest because the plants, although making a good growth, were not sufficiently vigorous to allow the development of the disease under any of the conditions tried. The results were apparently the same whether the limited growth was due to a lack of water, a scant food supply, or to some disease of the foliage. Plants that were stunted in their early growth showed a decreased susceptibility to the disease in their later development even if then severely forced. The experiments that follow show the results of various methods of forcing and also the modifying effect of other agencies when acting upon forced plants.

### EFFECTS OF SOIL MOISTURE

In the spring of 1909 a crop of tomatoes that was being grown in the college greenhouses as a demonstration of commercial methods became badly affected with blossom-end rot. The water supply of the plants was increased, but the disease continued to develop, finally destroying a large part of the crop. The failure of this generally recommended remedy led the writer to make a study of the disease. The relation of soil moisture to the trouble was apparently one of the important things to be determined.

Numerous experiments were made to find out the effect of drouth upon the disease. The results varied with the condition of the plants at the time of treatment and with the rapidity of the drying. Susceptible plants that have been subjected to sudden drying while in full activity have always shown an increase in the disease. The following table gives the results obtained by selecting plants that had shown approximately equal susceptibility to the disease and subjecting part of them to severe drying while heavy watering was continued on the others. After the drying the plants were again watered liberally. The different lots had different conditions of growth and also different amounts of fertilizer. Lots 2 and 4 received manure, while 1 and 3 did not.

| LOT | VARIETY | PER CENT OF ROT | |
|---|---|---|---|
| | | Dried | Not dried |
| 1 | Matchless..... | 14.0 | 8.5 |
| 2 | Matchless..... | 37.5 | 28.2 |
| 3 | Matchless..... | 28.1 | 12.0 |
| 4 | Earliana..... | 3.6 | 1.9 |

The contrasts are striking enough to convince one that dryness may play a part in producing the disease.

Susceptible plants have not shown any increase in the disease resulting from a reduction in the water supply when the change was made slowly; in fact gradually changing excessively watered plants to a more nearly normal condition tended to decrease the disease. The plants used in testing this point were grown in a soil that was half clay loam and half manure. Each plant received 260 grams of commercial fertilizer. The amount of water in the soil was kept at approximately 50 per cent during the first part of the season. (The effects of heavy watering are shown in figure 1.) With half the plants this watering was continued while with the other half the amount of water in the soil was gradually reduced to 11 per cent. The following results were obtained:

| | | PER CENT OF ROT | |
|---|---|---|---|
| | | Before July 30th | After July 30th |
| Earliana. | Heavily watered throughout season.... | 70.0 | 97.5 |
| Earliana. | Water decreased after July 30th..... | 67.7 | 82.1 |
| Matchless. | Heavily watered throughout season.... | 88.2 | 94.4 |
| Matchless. | Water decreased after July 30th..... | 87.2 | 83.1 |

It will be noted that the per cent of rot on the contrasted groups of plants was approximately the same the first part of the season, and that while the rot made a striking increase on the heavily watered plants the latter part of the season it failed to do so on the plants on which the water was reduced. None of the plants wilted, although those receiving the limited water supply sometimes approached the wilting point. All were vigorous at the close of the experiment. That the decrease in the water supply was severe enough to be felt by the fruit was shown by careful caliper measurements taken of particular tomatoes at various times. Fruit that was approximately $1\frac{1}{4}$ inches in diameter was selected for the work. At the end of eleven days after the change in watering was begun it was found that the diameter of the fruit on the heavily watered plants had made an increase of 46.9 per cent, while that on the lightly watered ones had increased but 22.2 per cent.

Plants subjected to frequent slight wiltings developed more diseased fruit than those receiving fewer but heavier wiltings. Plants were severely dried and a part of them restored to their normal water conditions gradually, and others abruptly, but there was no contrast in the amount of disease developed. Plants that were in a fairly vigorous condition but which had never shown any tendency to the trouble seldom produced any diseased fruit when subjected to either light or heavy wilting.

In another set of experiments a fairly constant difference was maintained in the water supply of the plants. In these experiments the plants were all treated alike till the fruit was well set and then gradually changed to the conditions desired. The various per cents of soil moisture given were obtained by constant differences in the amount of water applied to the plants. They are based on the condition of the soil about two hours after the plants had been watered. The watering was usually done in the morning. The above method of procedure was checked up by soil moisture determinations. The 65 per cent of water was obtained by setting the pails in pans of water and watering the soil from above in addition to keeping the pans filled. The plants in curves 1 and 2 were watered every second day. All of the others were watered daily and sometimes oftener. All of the experiments were made in the greenhouse.

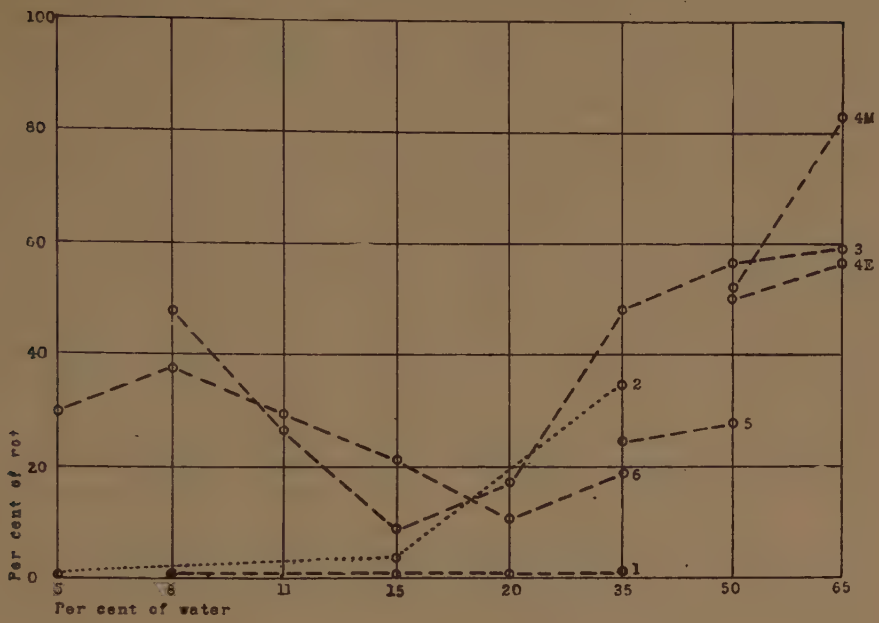


FIG. 1. See description in following table

| CURVE | VARIETY | SOIL | MANURE | GRAMS FERTILIZER PER PLANT | TIME OF FRUITING |
|---|---|---|---|---|---|
| 1 | | Sandy loam | None | Light applications | |
| 2 | Earliana | Sandy loam | ½ | 44 $NaNO_3$ 330 Superphos 0 KCl | March and April |
| 3 | Matchless | Clay loam | ½ | 24 $NaNO_3$ 48 Superphos 96 KCl | July and August |
| 4M | Matchless | Clay loam | ½ | 36 $NaNO_3$ 72 Superphos 144 KCl | July and August |
| 4E | Earliana | Clay loam | ½ | 36 $NaNO_3$ 72 Superphos 144 KCl | July and August |
| 5 | Matchless | Clay loam | None | 36 $NaNO_3$ 72 Superphos 144 KCl | July and August |
| 6 | Matchless | Sandy loam | None | 24 $NaNO_3$ 48 $Ca(H_2PO_4)_2$ 96 KCl | May and June |

Curve 1 represents several crops that failed to produce any rot, apparently because of insufficient fertilizer. The plants of curves 1 and 2 wilted repeatedly. With the exception of those having 5 per cent of water, the plants of the other curves were not definitely wilted at any time. The foliage on those having 8 per cent of water sometimes showed a lack of turgidity but never a definite drooping. The plants having 5 per cent of water were somewhat stunted by their treatment. The size of the plants increased with increases in water supply up to 20 per cent and in some cases to 30 per cent. There was little contrast in the size of the plants having 20, 30, 50 and 65 per cent of water, respectively. The plants having 50 per cent and 65 per cent of soil moisture had thicker, firmer leaves than the others and the foliage was not as dark green. There was sometimes a slight unevenness in coloration on these plants but never a

definite mosaic condition. The roots on these plants seemed elongated and the amount of branching and the number of root hairs were apparently decreased. An odor of decomposition was often given off from the heavily watered soil.

The results as shown in figure 1 give very striking evidence that the water supply is of great importance in the production and the control of the disease. The decreased amount of the disease on the plants of curve 6 that received 5 per cent of water and the practical lack of disease shown by the lightly water plants of curve 2 were apparently due to the lack of vigor in the plants concerned. Aside from these points the lines of figure 1 resolve themselves into a double curve, the disease being worst on the lightly watered and heavily watered plants and least on those receiving a moderate supply of water. This double curve would suggest that two factors are concerned, and that the disease might have two causes or else a single direct cause that might be initiated by either of two modifying agencies.

The increase in the disease when the water was reduced below the optimum gives further evidence that dryness is a factor in its production. It is evident, however, that excessive dryness is not essential to its development, for the plants that produced the most rot never wilted.

It seemed possible that the osmotic relations existing between the foliage and fruit might throw some light on this phase of the problem. Tests were made by the freezing point method to determine the osmotic value of the cell sap in the leaves and fruit of the same plant. The osmotic pressure in the cells of the fruit was found to vary from $7\frac{1}{4}$ to 9 atmospheres, while that in the leaves was 1 to 2 atmospheres greater in all cases. This would suggest that the leaves might draw water from the fruit or prevent it from going to the fruit in times of dryness and thus cause the latter rather than the former to receive the first shock resulting from a decrease in water supply. Chandler (1914) has shown that this is actually what occurs under certain conditions with both tomatoes and peaches. He found that when branches were removed from the plant and brought into the laboratory the leaves wilted much more quickly when the fruit was removed, and on the other hand the fruit shrivelled much more rapidly when attached to a leaf bearing branch than when removed from it. This power of the foliage of the detached branch to deprive the fruit of water doubtless holds also with plants in actively growing conditions.

It seems probable that the osmotic relations existing between the foliage and fruit may offer at least a partial explanation for the development of the disease on plants that have been subjected to considerable diurnal variation in water supply but have shown no sign of suffering from drouth. This hypothesis would help in explaining the left hand portion of the curves in figure 1, but is of little value in accounting for the right hand

part. It does not explain the greater development of the disease with 35, 50 and 65 per cents of moisture than with the 15 or 20 per cent. It should be noted also that with the plants having 65 per cent of soil moisture the diurnal variation was greatly decreased by a constant renewal of water from the pans in which the pails were setting.

As a further test of the effect of the uneven water supply in plants watered but once or twice a day, certain plants were given a continuous supply of water by means of a drip from a stopcock, while others received the same amount of water in one application. Each plant received three quarts of water per day. The soil was a sandy loam without manure. The following results were obtained:

| | *per cent of rot* |
|---|---|
| Watered once a day | 12.0 |
| Watered by continuous dripping | 14.2 |

The results furnish further evidence that the unevenness in the water supply on the heavily watered plants can not be held as the main cause of the large amount of rot.

It seemed possible that the application of large amounts of cold water might be detrimental to the plants on account of the somewhat sudden lowering of root temperatures. In order to test this, plants were watered only with water that had stood in the greenhouse for a day preceding its use, while others were watered in the usual way from the tap. The water applied to the former was approximately 23°C., while that applied to the latter was about 15°C. The usual temperature of the soil at the time of application was 21°C. The experiment was made on sandy loam. All of the plants were vigorous. The following results were obtained:

| | PER CENT OF ROT | |
|---|---|---|
| | First experiment | Second experiment |
| Receiving tepid water | 29.4 | 26.8 |
| Receiving cold water | 12.1 | 17.0 |

The results indicate that the lowering of the soil temperature tended to decrease the disease. It did not cause any decrease in the vigor of the plants. It seemed probable that the beneficial effects of the cold water should be attributed to the checking of soil or root activities that were favorable to the development of the disease.

The experiments with water have shown that the blossom-end rot may be produced by drouth, but that the condition of the plant at the time of the decrease in the water supply is of much greater importance than the degree of dryness to which it is subjected. They have also shown that heavy

watering may develop a susceptibility to the disease that can not be correlated with the growth and vigor of the plants and which can not be wholly attributed to unevenness in water supply. This tendency to the disease is often accompanied by odors of decomposition from the soil, and is decreased by lowering the soil temperature and also by decreasing the water supply.

### EFFECTS OF SOIL

In figure 1 it may be noted that with the experiments made in sandy soil the disease did not increase so greatly with the higher per cents of soil moisture as it did in the clay loam. This contrast would be still more striking if the amounts of water were estimated on a basis of per cent of saturation instead of on their relation to the weight of soil. In

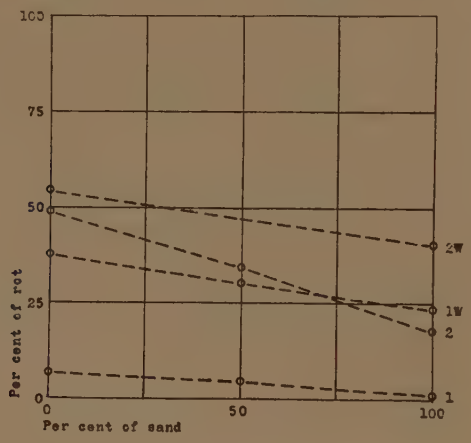


FIG. 2.

these experiments, however, the plants that furnished the data for the different curves were not all grown at the same time and under the same conditions. In another experiment the plants were all treated alike with the exception that sand and loam were present in different proportions. Each plant received 200 grams of commercial fertilizer. In addition to this those of curve 2 had manure mixed with the soil to make half the bulk. The plants were of the Matchless variety. Figure 2 gives the results obtained.

Curves $1^w$ and $2^w$, figure 2, show the per cent of water held by the different soils when saturated; $1^w$, when the soil was without manure, $2^w$, when manure was added. In considering these curves the perpendicular shows the per cent of water, and the base line the amount of sand in relation to the total bulk of soil exclusive of the manure. The curves indicate the

water capacity and physical condition of the different soils, but not the water available to the plants, as the soils were never kept saturated. The plants of the different lots were watered alike, each plant usually receiving two quarts per day. It was intended that the soil moisture should average as near 50 per cent of saturation as possible, but in order to have all the plants in equal vigor, it was found necessary to keep the water supply in the sandy soil relatively higher than in the loam.

For curves 1 and 2 the perpendicular indicates the per cent of rot and the base line, as before, the per cent of sand. It is evident that the addition of the sand to the loam caused a very definite decrease in the disease. The plants in half loam and half sand averaged a little more fruit per plant then the others, but there was nothing in the general appearance of the plants receiving different treatments to explain the difference in amount of rot. The loam must have furnished more food material than the sand, but all the plants were heavily fertilized, those of curve 2 especially so, and it does not seem propable that this difference in food supply could have been of importance. As has already been mentioned, there was no contrast in the vigor of the plants that could be correlated with differences in the amount of sand. It seems probable that the better aeration that resulted from the addition of the sand was the factor of greatest importance in decreasing the rot.

Straw, sphagnum, and manure were also added to loam in various proportions. The first two caused slight increases in the disease in every case, and the last very decided ones. The additions of the manure introduced a number of modifying factors, but with the straw and the moss the most important effects were probably upon aeration and water supply.

The above experiments indicate that the composition of the soil has a modifying influence on the development of the disease and suggest that the factors of drainage and aeration are of greatest importance.

### FERTILIZERS

*Manure.* As has already been mentioned, the addition of manure to the soil greatly increased the disease. Figure 3 shows the effects of fresh horse stable manure. With all the curves but 1M and 1E, the plants were closely watched, heavily watered, and never allowed to wilt or become dry. With all the curves but 4M and 4E the plants were grown outdoors and fruited in July and August. With 4M and 4E the plants were grown in the greenhouse and fruited in October and November. The base line shows the per cent of manure, the perpendicular the per cent of rot.

Increasing the amount of manure increased the rot in all cases. The contrast was greater on a sandy loam than on sand. It is evident that

applying the amount of manure often recommended for greenhouse tomatoes (manure to make $\frac{1}{3}$ or $\frac{1}{2}$ the bulk of the soil) may greatly increase the disease and that heavier applications are still more serious.

The results as a whole are very striking but are difficult to interpret because of the complexity of the factors concerned. The fact that some of the plants were forced more than the others probably furnishes a partial explanation for the contrast in the amount of the disease, but there are apparently other modifying factors. The plants in soil that was one-third manure were very similar in size and general vigor to those in soil that was one-half manure. The plants in both these lots were slightly larger than those without manure and also larger than those in soil that was

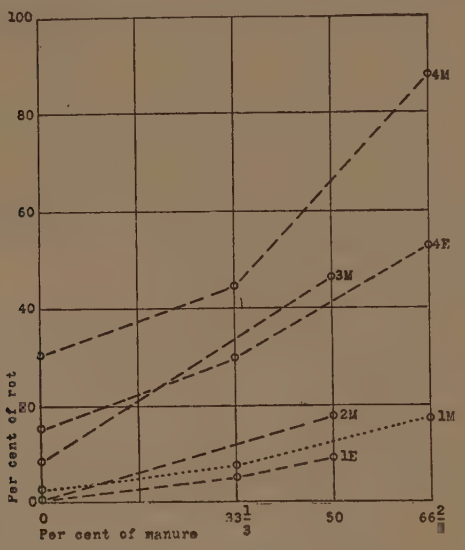


FIG. 3. 1M and 1E. Matchless and Earliana tomatoes in loam, receiving 100 grams of commercial fertilizer per plant. Lightly watered and sometimes wilting.

2M. Matchless plants in sand, receiving 200 grams of commercial fertilizer per plant.

3M. Same as 1M, but in soil that was half sand and half loam.

4M and 4E. Matchless and Earliana plants in loam, receiving 150 grams of fertilizer per plant.

two-thirds manure. There was, therefore, little correlation between the vigor of the plants and the per cent of rot. The contrast in the size of the plants without manure with those receiving manure was too small to account for the difference in the severity of the disease, while with the higher percentages of manure there was a striking increase in the rot, accompanied by no increase in the vigor of the plants. The unfavorable

effects of the manure, apparently, can not be attributed to the forcing of the plants. They can not be entirely due to the difference in the physical condition of the soil, for, as has already been mentioned, similar amounts of straw caused but very slight increases in the disease. It seems probable that the nature of the food material added and the changes in the soil flora may have been of importance in increasing the disease.

In another experiment with manures the effect of partial sterilization was tested. The manure differed from that mentioned above in that it was well rotted. It was mixed with a rather heavy clay loam in amounts sufficient to make one-third the bulk. For part of the plants the prepared soil was heated to 100°C. for 20 minutes. Some unsterilized soil clung to the roots of the plants in resetting so that complete sterility was not secured. The plants in both the unsterilized and the partially sterilized soil were considerably checked at first by the effects of the manure, but all of them appeared to recover later, although they were never quite so large as the plants that received no manure. The following results were obtained:

| | PER CENT OF ROT | |
|---|---|---|
| | First experiment | Second experiment |
| In unsterilized soil | 0.0 | 0.0 |
| In partially sterilized soil | 28.6 | 10.0 |

The fact that the plants had been checked in their growth complicates the situation, but the results would indicate that partial sterilization of the soil and manure favored the disease. It seems probable that the heating produced chemical and bacteriological changes in the soil that tended to increase the rot.

*Commercial fertilizers.* Experiments were also made with commercial fertilizers. In the early part of the work none of the tests gave results of interest, apparently because the plants were rather lightly watered and therefore not sufficiently vigorous to develop the disease. Different amounts of fertilizer were tested, varying from 0 to 600 grams per plant, also various quantities of phosphate, nitrate and potash, but practically no contrast was obtained under any of these conditions, as all of the plants were almost entirely free from the disease.

In the above experiments the plants were watered only as they appeared to approach dryness, usually once every two or three days. In the later experiments the plants were watered daily and the amount of water in the soil was kept as near 18 per cent as possible. With liberally watered

plants increases in the amount of fertilizer increased the susceptibility to the disease.

The following results were obtained with Matchless plants growing in sandy loam and fruiting in May and June. The fertilizer consisted of four parts potassium chloride, two parts superphosphate and one part of sodium nitrate.

| GRAMS OF FERTILIZER PER PLANT | PER CENT OF ROT |
|---|---|
| 0 | 8.3 |
| 75 | 6.8 |
| 168 | 23.8 |

All of the plants made a good growth but those receiving fertilizer were somewhat more vigorous and produced a larger crop.

Experiments were made to determine the effect of discontinuing the fertilizing on plants that had already developed a strong tendency to the disease. Plants were selected that were as nearly alike as possible. They were carefully watched and not allowed to wilt. They were in soil that was one-third manure, and each plant had received 260 grams of fertilizer prior to the beginning of the test. The plants in one lot received no further fertilizer, while in the other they received two additional applications of 52 grams per plant. The last application on the former lot was made July 19; the latter was fertilized on July 31 and August 8. The following table shows the amount of rot developed before and after the change in treatment. The records extended from July 19 to August 22.

| | PER CENT OF ROT | |
|---|---|---|
| | Before July 31st | After July 31st |
| Earliana. Fertilizer discontinued..... | 84.4 | 61.1 |
| Earliana. Fertilizer continued..... | 70.0 | 97.5 |
| Matchless. Fertilizer discontinued..... | 94.7 | 87.7 |
| Matchless. Fertilizer continued..... | 88.2 | 92.4 |

The different treatments did not produce an appreciable contrast in the appearance of the plants. The results indicate that stopping the applications of fertilizer on severely forced plants tends to decrease the rot. They also furnish further evidence of the converse statement that the rot is favored by forcing the plants with fertilizer.

Experiments were made to determine the relative importance of the different constituents of the fertilizer in the production of the disease. Plants in a heavy clay loam made a poor growth when the superphosphate was omitted from the fertilizer and therefore developed but little disease. Increasing the phosphate from 50 to 100 grams per plant, however, had little effect upon the amount of the disease. Other fertilizer experiments also indicated that there was but little relation between the quantity of phosphate applied and the per cent of rot developed.

Potash was of much greater importance in determining the amount of disease. The results shown in figure 4 were obtained with Matchless tomatoes on a heavy clay loam. The base line shows the amount of KCl used and the perpendicular the per cent of rot.

The disease increased rapidly and consistently with the increase in amount of potash applied. There was little or no contrast in the growth and general vigor of the plants receiving the different treatments. A

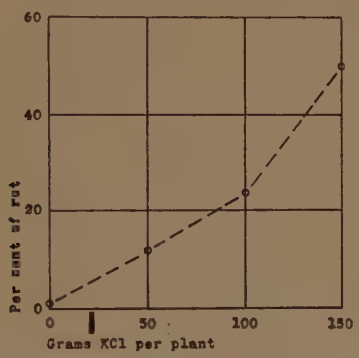


FIG. 4

large per cent of the disease on the plants receiving heavy applications of potash developed internally, the rot appearing to have its origin from lesions in the fleshy placentae.

The effect of various amounts of nitrate was also tested. Figure 5 shows the results obtained with sodium nitrate. In addition to the nitrogenous fertilizer each plant received 48 grams of superphosphate and 96 grams of potassium chloride. The fertilizers were applied in three equal quantities. The plants were carefully watched and did not become dry or wilted at any time. The amount of nitrate is indicated on the base line and the per cent of rot on the perpendicular.

The results indicate that increasing the applications of sodium nitrate tends to decrease rather than increase the disease. The plants receiving

the larger amounts of nitrate had slightly more vigorous foliage than the others, but there was little difference in the general appearance of the plants under the different treatments.

The results obtained in the experiments with phosphate, potash and nitrate indicate that the increase in the disease reported above as accompanying an increase in commercial fertilizer must have been largely due to the potash present.

The effects of other nitrogenous substances were compared with those of nitrate of soda. The experiments were made with Matchless tomatoes on a heavy clay loam. The plants were fruiting in May and June. All of the plants received light applications of nitrate of soda during

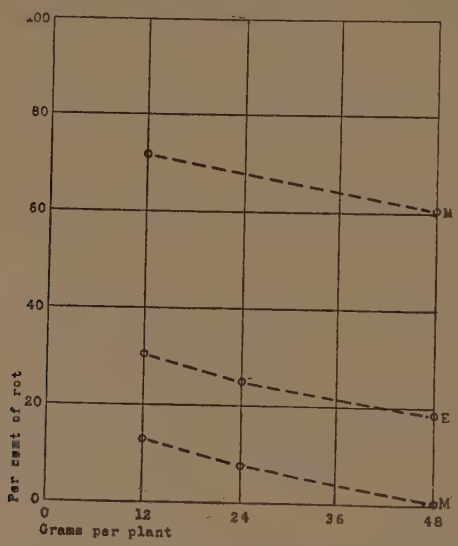


FIG. 5. M. Matchless tomatoes on a light loam and fruiting in October and November.

E. Earliana tomatoes on a light loam and fruiting in October and November.

M.[1] Matchless tomatoes on a heavy clay loam and fruiting in May and June.

their early development. The heavier applications of this salt were begun when the fruit was well set. The applications of dried blood and ammonium sulphate were made about two weeks earlier in each case than those of sodium nitrate. In addition to the nitrogenous fertilizer each plant received 50 grams of superphosphate and 100 grams of potassium chloride. The plants were usually watered but once a day. The soil moisture was kept as near 18 per cent as possible. The following results were obtained:

| LOT | TOTAL GRAMS NITROGENOUS FERTILIZER | | | PER CENT OF ROT |
|---|---|---|---|---|
| | $NaNO_3$ | $(NH_4)_2SO_4$ | Dried Blood | |
| 1 | 48 | | | 0.0 |
| 2 | 24 | | | 7.1 |
| 3 | 12 | | | 16.0 |
| 4 | 12 | | 30 | 22.3 |
| 5 | 12 | 24 | | 50.4 |

The fertilizer was not applied in all cases in the amounts originally outlined. Lots 1 and 5, also lots 2 and 4, agree quite closely in the total amount of nitrogen they received. It seems evident that under the conditions in which the plants were grown, fertilizers that are likely to furnish nitrogenous food in the form of ammonium compounds are much more favorable to blossom-end rot than nitrate of soda.

In another experiment certain plants were given 1 liter of one-fifth M solution HCl daily in connection with the regular watering. Others were similarly treated with one-fifth M solution $NH_4OH$. The former developed no rot. At the end of ten days from the beginning of the treatment a number of tomatoes on the plants receiving $NH_4OH$ had become black and rot-like within. The fruit had a collapsed appearance but was still green on the surface. At this time the foliage still looked normal but later the lower leaves began to turn yellow and die. Although the plants were placed under quite abnormal conditions, the experiment furnishes further evidence of the sensitiveness of the fruit to ammonium compounds.

*Sugar.* A test was made of the effects of adding cane sugar to the soil. The plants were of the Matchless variety, received 156 grams of fertilizer each, were in soil composed of half loam and half manure, and were rather lightly watered. Fifteen grams of cane sugar were applied to each of the treated plants every day for eleven days. On part of the plants the treatment was continued five days longer. No rot developed on the treated or check plants until five days after the last application of sugar. The following results were obtained.

| *Total grams of sugar per plant* | *Per cent of rot* |
|---|---|
| 240 | 70.0 |
| 165 | 27.2 |
| 0 | 25.0 |

The plants receiving sugar approached the wilting point several times and it is possible that the effect of the sugar upon the available water supply may have had an influence upon the production of the disease. The treated soil, however, became quite sticky and heavy and the fact that

the rot developed at such a late date gave ample time for very decided changes in bacterial activities to have resulted from the application of sugar.

Munter and Robson (1913) found that adding sugar to either light or heavy soil decreased the rate at which ammonium sulphate was changed to nitrate. Other writers have reported heavy applications of sugar as having a depressing effect upon the nitrate content of the soil. In the light of the results obtained with nitrogenous fertilizers it seems probable that the increase in the disease resulting from the application of sugar may have been largely due to an increased ammonium content in the soil and an accompanying decrease in the nitrate content.

*Lime.* Experiments were made to determine the effects of lime upon the disease. In the first test each plant was given 18 grams of pure $CaCO_3$. All of the plants were grown in soil composed of half loam and half manure and each plant received 260 grams of commercial fertilizer. All were heavily watered. The following results are based on the total yield of sound and unsound fruit.

| | PER CENT OF ROT | |
|---|---|---|
| | Matchless | Earliana |
| With lime | 79.3 | 69.5 |
| Without lime | 92.9 | 90.0 |

The treated plants had considerably less rot than the untreated. The fruit was rotting badly at the time the lime was applied. The limed plants showed a decrease in rot after treatment, while the rot continued to increase on the checks. This point is shown in the following table.

| | | PER CENT OF ROT | |
|---|---|---|---|
| | | Before time of treatment | After time of treatment |
| Matchless. | Receiving lime | 87.8 | 68.3 |
| Matchless. | Without lime | 85.0 | 98.1 |
| Earliana. | Receiving lime | 75.2 | 66.1 |
| Earliana. | Without lime | 81.9 | 95.1 |

In a second experiment the effect of $CaCO_3$ was tested on plants growing in sandy loam that was free from manure and contained but little turf. Each plant received 168 grams of commercial fertilizer. The fertilizer and also the lime was applied in three equal amounts. The plants were fruiting in May and June. The soil moisture was kept at as near 18

per cent as was possible with daily waterings. The following results were obtained:

| *Grams $CaCO_3$ per plant* | *Per cent of rot* |
|---|---|
| 36 | 16.3 |
| 0 | 23.8 |

The results indicate that lime may have a beneficial effect even when the amount of organic matter in the soil is not excessive. The two sets of experiments seem to leave no question but that at least under certain soil conditions lime may be of value in reducing the disease.

In a third experiment a commercial hydrated lime containing a considerable per cent of magnesium was used. Each plant received two applications of 30 grams each. Each plant also received 100 grams KCl, 50 grams superphosphate, 30 grams dried blood, and 12 grams $NaNO_3$. The soil was a heavy clay loam without manure. With part of the plants the soil moisture was kept at about 30 per cent, with others at about 15 per cent, and in a third lot at about 8 per cent. At first the lime showed some tendency to increase the disease on all of the plants, but later it produced a decided decrease on those that were heavily watered. The following table gives the final results:

| WATERING | PER CENT OF ROT | |
|---|---|---|
| | Receiving lime | Without lime |
| Heavy | 16.7 | 30.4 |
| Medium | 22.2 | 22.0 |
| Light | 15.8 | 12.5 |

The results show that the beneficial effects of lime decrease with a decrease in soil moisture. They indicate that its value lies in some corrective action that decreases the harmful effects of heavy watering.

It is possible that the slight increase in the disease after the applications of lime and also the increase on the dry plants is due to some toxic effect of the calcium hydrate or its impurities, but there was nothing in the growth and general appearance of the plants to indicate any such effect.

## FIELD EXPERIMENTS

Some of the points already reported were given a further test in the field. The plants were of the Matchless variety and were grown on a heavy clay loam that had received a spring dressing of fifteen tons of manure to the acre. There were numerous showers early in the season,

keeping the plants in a vigorous condition, but in July the soil became quite dry and the plants were considerably checked. It was during this dry weather that most of the disease developed. There were forty plants in each plot. The tomatoes were not staked. The following results were obtained:

| PLOT | GRAMS OF FERTILIZER PER PLANT | PER CENT OF ROT |
|---|---|---|
| 1 | Acid phos. 60 KCl 160 Dried blood 50 | 31.8 |
| 2 | Acid phos. 60 KCl 80 Dried blood 50 | 34.2 |
| 3 | Acid phos. 60 KCl 80 Dried blood 50 Hydrated lime 100 | 30.2 |
| 4 | Acid phos. 60 KCl 80 Dried blood 50 Hydrated lime 200 | 30.8 |
| 5 | Acid phos. 60 KCl 80 Dried blood 50 $(NH_4)_2SO_4$ 20 | 49.4 |
| 6 | Acid phos. 60 KCl 80 Dried blood 100 | 52.0 |
| 7 | Acid phos. 60 KCl 80 Cotton seed meal 180 | 48.7 |
| 8 | Acid phos. 60 KCl 80 $NaNO_3$ 50 | 36.7 |
| 9 | Acid phos. 60 KCl 80 $NaNO_3$ 12 | 32.9 |

The plants were quite uneven in their growth and many of them more or less affected with mosaic. The results give some points of interest when compared with those obtained under greenhouse conditions. They indicate that under drouth conditions potash has no tendency to increase the disease and lime little tendency to decrease it, but that nitrogenous fertilizers favor its development. Nitrate of soda showed slightly less tendency to increase the disease than ammonium sulphate and organic fertilizers having an equivalent amount of available nitrogen.

## OSMOTIC VALUE OF CELL SAP

The osmotic value was determined of the cell sap of fruit grown under different conditions. Beckmann's freezing point method was used in the determinations.[3] Tomatoes that were 1 to $1\frac{1}{2}$ inches in diameter were used in the work. Only the blossom half of the fruit was taken. The following table shows the contrast between the average concentration of the cell sap in sound fruit from stunted plants and of similar fruit from forced plants. The results are given in terms of atmospheric pressures.

| | *Osmotic pressure in atmospheres* |
|---|---|
| Stunted plants | 7.26 |
| Forced plants | 7.87 |

A similar study was made of sound fruit and similarly grown fruit that showed incipient rot. With the latter there was the first stages of a watersoaked condition on the surface, while the tissue beneath was begin-

[3] The osmotic determinations were made by S. H. Katz of the Chemistry Department of New Hampshire College.

ning to darken. The following table gives the average concentrations of cell sap of the two kinds of fruit. The results are based on determinations made on the fruit from two different crops and from more than a dozen plants.

*Osmotic pressure in atmospheres*

| | FIRST LOT | SECOND LOT |
|---|---|---|
| Sound fruit | 7.44 | 7.87 |
| Fruit with incipient rot | 8.31 | 8.87 |

The comparison of the osmotic pressure in stunted and forced plants, as well as that on sound and affected fruit, seems to indicate that a high osmotic pressure in the cell sap is closely associated with the occurrence of the disease.

Titrations of the cell saps mentioned above showed that those having the higher osmotic value were slightly more acid than the others, but the difference in acidity was not sufficient to account for the difference in osmotic pressure.

## TRAUMATISMS

Efforts were made to produce effects similar to the disease by means of mechanical agencies. The tomatoes were left on the vine after treatment. It was found that the blossom portions of tomatoes could be burned by the sun's rays, frozen with carbon dioxide, or killed by electric currents without the development of any condition closely resembling the rot. $\frac{1}{2}$M solutions of $NH_4OH$ and HCl were injected into fruit by means of a hypodermic needle. The effects were in no way similar to the disease. Reducing the water supply of the fruit by means of cuts and bruises on the supporting stem did not induce the disease.

Bruising the fruit caused spots to develop that bore some resemblance to the rot. The tissue blackened as in the rot but usually dried up quickly, becoming papery rather than having the leathery consistency of the rot. When turgid tomatoes were compressed in the axial direction with a twisting motion and in such a manner as not to bruise the surface of the fruit, results were obtained that bore a very close resemblance to the blossom-end rot. Bruises on the side or on the stem portion of turgid tomatoes were often followed by the development of a typical rot at the blossom end.

## RAPIDITY OF DEVELOPMENT

When the disease was produced by drying the plants or by other means, careful records were kept of the time required for the effects

to become evident. Three or four days after the action of a causal agent an experienced eye could pick out the fruit that had been seriously affected. Two or three days later a watersoaked condition would appear on the blossom portion of the fruit and finally the tissue would become black and rot-like.

### HISTOLOGICAL

A study was made of the diseased tissue and of tissue from fruit grown under various conditions. Various methods of fixing, imbedding, and staining were used. Both Juel's solution and weak Flemming gave satisfactory results as fixing agents. Much better results were obtained with Bergamot oil than with xylol in transferring the material to paraffin. Various contrast stains were used, but none were found more satisfactory than the Flemming triple stain. Freehand sections of fresh material were compared with the prepared slides and the effects of various microchemical reagents tested.

As has already been mentioned, the rot may start as a minute watersoaked area on the surface of the blossom portion of the fruit, later enlarging, turning dark and spreading deep into the flesh, or it may start internally in the blossom end portions of the fleshy placentae either as small lesions or as minute dark specks adjacent to the seeds and later spread to the surface.

A histological study of the early stages of the disease showed that the cells of the affected tissue were nearly always gorged with starch. Compound grains were common, but the single form predominated. In many cases there were very large numbers of extremely minute grains. In the larger starch grains fissures were common. In some cases, especially in cells near the vascular tissue, there was little or no starch present, but numerous small particles of oil that often appeared to be closely associated with granules of congested protoplasm (see plate XXV, fig. 2). This condition was particularly common on fruit from heavily watered plants both in the diseased tissue and in that adjacent to it.

The tissue adjacent to the rot showed little or no contrast in the above points with that in which the disease was developing. Tissue from fruit that was showing no tendency to the disease had less starch, fewer small grains and fewer fissured ones. Oil was very seldom present, and a granular congested condition of the protoplasm was not observed.

When the disease started internally the first evidence of it was found in the collapsing or tearing of certain cells or groups of cells of the fleshy placentae, usually adjacent to vascular tissue and in the neighborhood of the seeds (see plate XXVI, fig. 1). In some cases the tissue adjacent to the seeds showed a puffed, oedematic condition.

## INTERPRETATION OF RESULTS

The results that have been obtained in the various experiments have further interest when considered in their relationships. The disease has been produced on vigorous plants by a sudden decrease in the available water supply, but other factors than vigor and dryness have been shown to be of importance in determining the occurrence of the trouble. It has resulted from the wilting of plants only when their photosynthetic and metabolic processes were apparently in great activity. It has been produced much more readily and uniformly by an excessive water supply than by a scant or intermittent one. Plants receiving a moderate supply of water have developed far less rotten fruit than either lightly or heavily watered ones. With liberal watering there has been less disease on sandy soil than on clay loam. Partial sterilization of manured soil has favored the disease. Keeping greenhouse soil at rather high temperatures during the growth of the plant has had a similar effect. Applications of manure have increased the disease out of all proportion to the increase in the vigor and growth of the plants. Ammonium sulphate, dried blood and cotton seed meal have increased the rot more than nitrate of soda. On liberally watered greenhouse plants potash has favored the disease, while lime and nitrate of soda have decreased it.

It will be noted that the soil factors that have decreased the disease are all such as favor oxidation, while those that have increased it, aside from drouth, are either of such a nature as to check oxidation or else to increase the organic compounds that would require oxidizing.

Numerous related conditions have been reported by other writers. Schreiner and Reed (1909) found that soil oxidation was favored by nitrate of soda and by calcium carbonate, but depressed by potassium. Various authors have called attention to the strong nitrifying power of arid soils. Harrison, Stockdale and Ward (1912) found that in a dry season there was almost no ammoniacal nitrogen in the soil and a relatively high proportion of nitric nitrogen, but that when the rainy season began the conditions were soon reversed. Lipman, Brown and Owen (1910) reported that ammonification increased with an increase in soil moisture up to 16 per cent of water and nitrification up to 9 per cent of water. Hutchinson (1912) found that when the soil moisture reached 25 per cent rapid reversion of nitrates took place.

The depressing effect upon nitrification of agencies favoring the putrefactive bacteria has been pointed out by various writers. This has been found true whether the conditions favoring putrefaction were brought about by partial sterilization, by excessive watering, or by the addition of sugar, starch, straw, or other organic matter to the soil.

In the light of the above investigations and with the data obtained from the various experiments already reported, there seems to be little doubt but that much of the blossom-end rot that occurs on liberally watered plants is due to the development of harmful humic and ammonium compounds at the expense of the nitrate content of the soil. With this interpretation of the results the heavily watered plants might be considered as growing under conditions somewhat akin to drouth, the large amount of toxic substances present increasing the water requirements. The remedy, however, is to be found in the prevention of the development of such conditions rather than in an increase in the water supply.

It has already been noted that the cell sap of susceptible tissue has a high osmotic value. Greenhouse experiments have shown that KCl tends to increase the disease, and the important part that potash plays in producing turgor is generally recognized. The fact has also been mentioned that the tomato is most susceptible when it is from $\frac{3}{4}$ to $1\frac{1}{2}$ inches in diameter. This is a time when the fruit is beginning its most rapid swelling. It should also be noted here that in susceptible tomatoes the internal tissue nearly always shows signs of having been under great pressure, the large air spaces being entirely excluded from all parts of the fruit and the blossom portions of the fleshy placentae being forced tightly against the wall of the cavity. The blossom half of the fruit appears to be under the greatest strain, the placentae being compressed and the ovary wall apparently tightly stretched by the force of the internal expansion. As has already been mentioned, an oedematic condition is sometimes found in the tissue adjacent to the seeds. Tomatoes that have a large number of locules have been found more susceptible to the rot than those with a smaller number.

In view of these facts it seems probable to the writer that turgor is sometimes a factor of importance in the development of the disease. It has already been pointed out that the rot sometimes starts from internal lesions. The effect of the pressure upon the concentration and composition of the cell sap might also be a question worthy of consideration. If turgor is of importance in the production of the disease, it is probably so, however, only under certain conditions, for lesions may occur in the tomatoes without the development of the rot and diseased fruit does not always show signs of having been under pressure.

When the rot is once started bacteria and fungi usually gain entrance to the tissue and assist in the destruction of the fruit. The writer is convinced, however, that the disease sometimes spreads from an initial point to involve a large part of the blossom half of the fruit without the aid of foreign organisms. Perhaps this is brought about by the fact that all of the blossom portion of the tomato has suffered from the same or

similar shocks, the effects becoming evident in some parts earlier than in others, but it seems possible that in fairly turgid fruit the contents of the disrupted cells may be instrumental in advancing the disease into adjacent tissue. It is possible that the harmful effects might come from the mere cutting off of aeration or from harmful substances developed in the breaking down of the cell sap. It seems probable that the aeration of the tomato is poor, for the skin is almost entirely destitute of stomata. It is interesting to note in this connection that Molliard (1909) found that in the process of death when deprived of oxygen certain plant tissues developed ammonia.

## CONCLUSIONS

The experiments reported above seem to justify the following conclusions:

1. The blossom-end rot of the tomato is not due primarily to bacteria or fungi.
2. Plants are most susceptible when in a condition of great activity.
3. Either continued excessive watering or a sudden check in the water supply may produce the disease.
4. With liberally watered greenhouse plants potassium chloride increases the disease and lime and sodium nitrate decrease it. These facts have not been found to hold true under field conditions.
5. Ammonium sulphate, dried blood and cottonseed meal have increased the disease more than sodium nitrate containing an equivalent amount of nitrogen.
6. Heavy applications of horse stable manure have increased the disease out of proportion to the increase in vigor of the plants.
7. When well supplied with water plants on a sandy loam have developed less disease than those on a clay loam.
8. Raising the soil temperature of greenhouse plants has increased the disease.
9. The writer is of the opinion that the increase in the disease from heavy watering is due to the development of harmful humic and ammonium compounds and an accompanying decrease in nitrates.
10. Susceptible tissue has more starch and more oil than normal tissue and its cell sap has a higher osmotic value.
11. The protoplasm in the cells from the fruit of the heavily watered plants is more granular and contains more oil than that of the lightly watered ones.

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## EXPLANATION OF PLATE XXIV

FIG. 1. An early stage of blossom-end rot, showing three water-soaked areas, one of which is turning dark.

FIG. 2. A longitudinal section of the tomato shown in figure 1, taken through the central one of the three spots. Note the collapsed placenta beneath.

FIG. 3. A longitudinal section of the tomato shown in figure 1, taken through the small dark spot.

FIG. 4. An early stage of blossom-end rot, showing many points of origin. The tissue was not affected to a greater depth than one millimeter at any point.

FIG. 5. An early stage of the rot.

FIG. 6. A later stage of blossom-end rot.

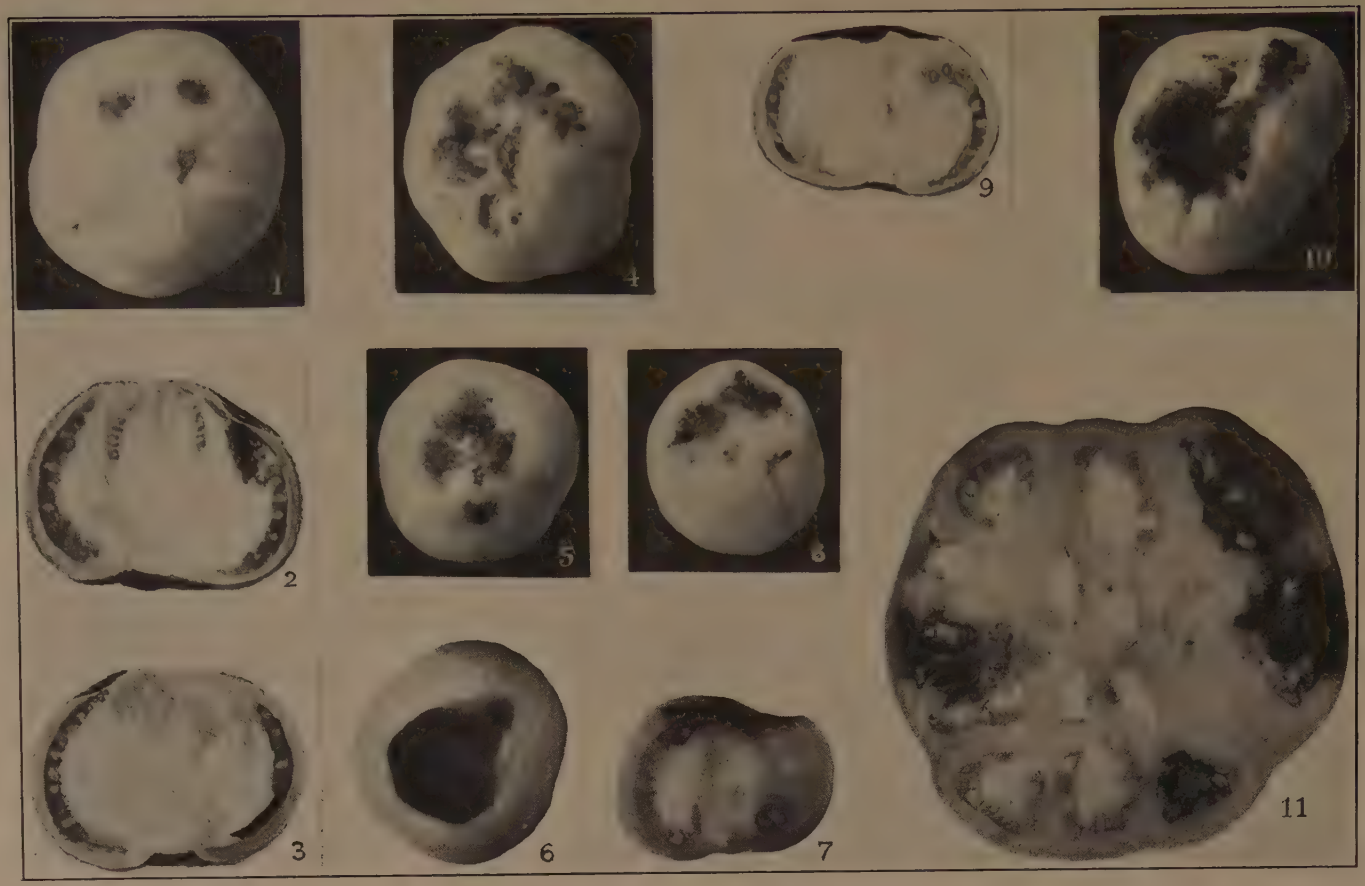
FIG. 7. Longitudinal section of the tomato shown in figure 6.

FIG. 8. A common form of the rot. The fleshy placentae beneath were also affected.

FIG. 9. A longitudinal section of the tomato shown in figure 10.

FIG. 10. A rot of the same type as shown in figure 4, but a later stage.

FIG. 11. A cross-section of a tomato that showed scarcely any external evidence of disease. Note the various beginnings of the disease within.





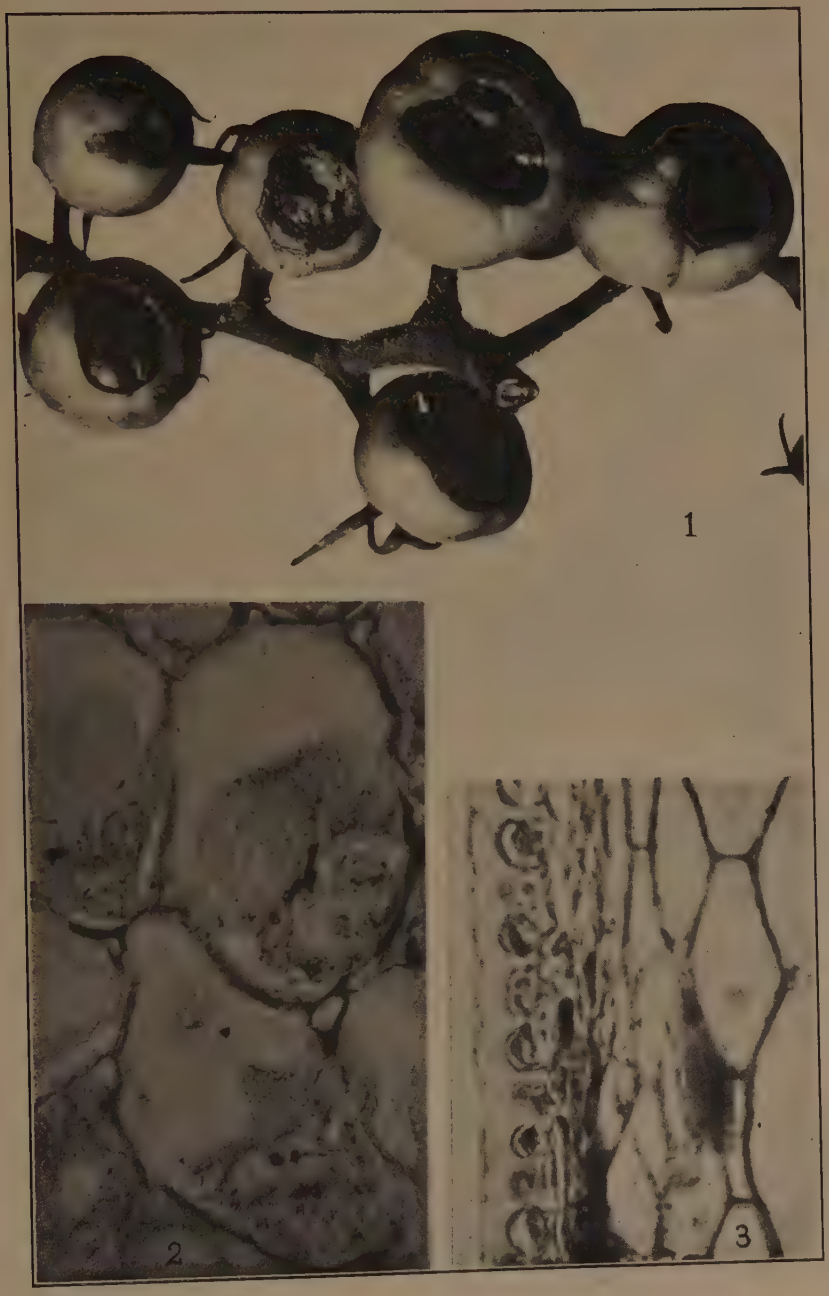

BROOKS: BLOSSOM-END ROT OF TOMATOES

## Explanation of Plate XXV

Fig. 1. A cluster of tomatoes showing various stages of blossom-end rot. The variety was a half blood Earliana.

Fig. 2. Cells from the margin of the rot tissue. The protoplasm is granular and contains droplets of oil.

Fig. 3. The margin of a watersoaked area. The cells just beneath the epidermis are breaking down.



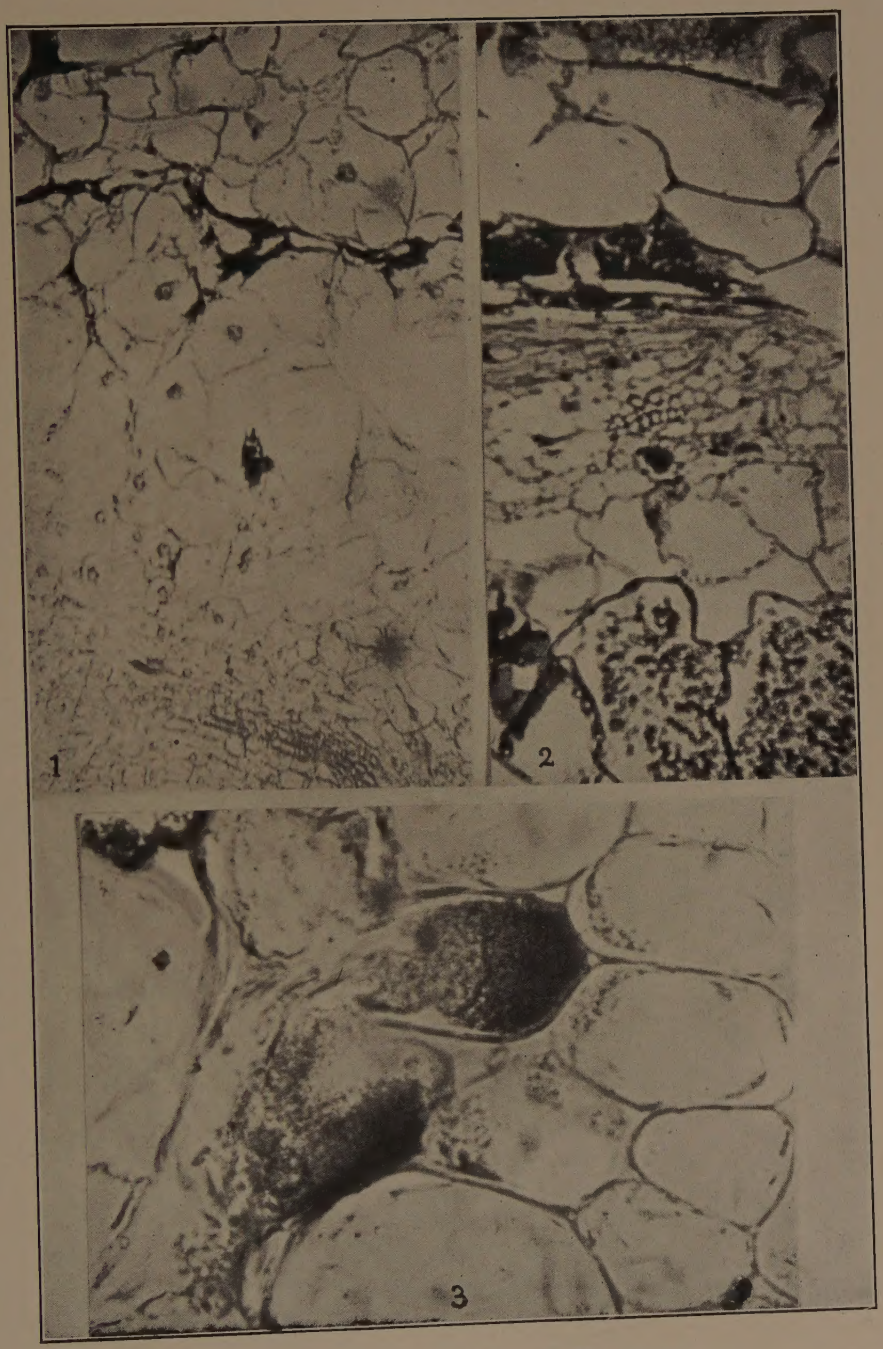

BROOKS: BLOSSOM-END ROT OF TOMATOES

## Explanation of Plate XXVI

Fig. 1. Very early stage of the disease as it is often found in the tissue adjoining the seeds. Some of the cells have collapsed and others are unduly enlarged.

Fig. 2. Tissue showing heavy deposits of oil in the cells adjacent to the vascular bundle. The section was taken from a healthy tomato on a plant that had received heavy applications of potash.

Fig. 3. Bacterial invasion of tomato tissue. The border between the diseased and the healthy tissue is shown.

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